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The harmonic representation of the annual temperature variation in different parts of the British Isles

by

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1. This work forms part of the programme outlined in previous papers by Craddock (1955) (1) and (2) for providing reliable meteorological normals on the basis of the harmonic analysis of the annual variation. It presents temperature normals for all parts of the British Isles in a form from which it is easy to calculate the numerical value for any day of the year. It has been shown by Craddock (1) that over most parts of Europe the annual variation of the daily mean temperature can be represented for most purposes by the two term harmonic form

$$T = a_0 + a_1 \cos\theta + b_1 \sin\theta + a_2 \cos 2\theta + b_2 \sin 2\theta$$

or

$$T = a_0 + A_1 \cos(\theta - \phi_1) + A_2 \cos 2(\theta - \phi_2)$$

where θ is measured from zero at midnight on December 31 and $a_0\, a_1\, b_1\, a_2\, b_2$ are parameters which differ from one station to another. It also appears probable that in some areas there are some small deviations from the two term harmonic form associated with particular dates, which can be called singularities, of which magnitude (and permanence or otherwise) can only be established by much more elaborate investigation than has been possible up to date. The basic data on which the form (1) was justified consisted in 5-day mean temperatures for non overlapping periods covering the year, and the methods used are applicable only to the comparatively few stations for which these data are available.

However, if the principle is accepted that two harmonic terms are enough to give a very good approximation to the form of the annual temperature variation, then the form can be fitted to monthly mean temperatures. This has been done in a later paper (Craddock (1955) (2)) where results are given for a network of 305 stations spread over the Northern Hemisphere, and the large scale variation of the harmonic parameters over the Northern Hemisphere is discussed with illustrative charts. The harmonic parameters have also been used to provide by harmonic synthesis tables of the normal value of the air temperature at 5-day intervals throughout the year, and these form the basis of a study of the synoptic variations of large scale temperature anomalies, which is now being carried out in the Forecasting Research Division of the Meteorological Office.

2. The present paper follows the lines of the last, but is concerned only with the British Isles. Its main purpose is to provide a reliable means of estimating the normal temperature in all parts of the country at all times of the year, and for all purposes, including the estimation of the temperature

/anomaly.

anomaly. It is also intended to throw light on the variation of the harmonic parameters with distance from the coast and, within the limits imposed by the rather low relief, with altitude. Most of the basic data were monthly mean temperatures for the new international period 1921-1950 taken from an official publication (3). 160 stations were chosen, including all for which the monthly means were based on data for the whole 30 years and about 45 others to cover gaps in the network. Most of the incomplete records covered 20 years or more.

These data provided a reasonably good cover over Great Britain. For Ireland 14 stations were used, for which most of the 30-year mean temperatures were calculated in the Forecasting Research Division. For stations in Eire the monthly mean temperatures were tabulated from the following sources:-

(a) for years up to 1940 from the Monthly Weather Reports of the British Meteorological Office,

(b) for 1940 to 1947 from values supplied by the courtesy of the Irish Meteorological Service, Dublin, and

(c) for years 1948 onwards, from the Monthly Weather Reports of the Irish Meteorological Service.

The harmonic parameters were calculated by the method already described (2) but for most stations the actual computation was done on the Manchester University electronic computer under the direction of Mr. F.H. Bushby. Full details of all the stations used are given in Table 1, and the values of the harmonic parameters are in Table 2. Figs. 1 to 6 show the more interesting features of the geographical distribution of these parameters.

3. (i) The annual mean temperature a_0

Fig. 1 shows the annual mean temperatures taken from Table 2 and reduced to mean sea level. It is included for comparison with similar maps based on earlier data, for example, that in the Climatic Atlas of the British Isles (4) which relates to the basic period 1901-30. Comparing 1901-30 with 1921-50 there seems to have been an increase of from half to one degree Fahrenheit in nearly all areas. Fig. 1, which shows the observations as well as the isopleths, shows several interesting local features of which a full discussion would run outside the scope of this paper.

(ii) The semi-amplitude of the first harmonic

Fig. 2 shows the semi-amplitude of the first harmonic. Over most of England the values are very uniform, ranging from about 11°F. to 12.5°F. but there is a rapid decrease near the coasts of Scotland, Wales and South West England. The mountain stations in Scotland seem to agree quite well with their lowland neighbours, though they may perhaps give a little support to the suggestion, based on data for German mountain stations (1) that the amplitude aloft is less than at neighbouring stations near sea level.

For Ireland the general picture is similar, with values of 9° to 10°F. over most of the country, including it seems much of the east coast, but with values about 7.5° to 8°F. on the south-west, west and north-west coasts.

(iii) The phase of the first harmonic

The phase of the first harmonic, ϕ_1 is given in Fig. 3 by the calendar date on which this harmonic attains its maximum. The date varies from the 23rd or 24th July inland over most of England and Ireland but is consistently later on the coasts, being latest of all in south-west England and Wales. The mountain stations can hardly be said to show any systematic difference from their lowland neighbours.

/(iv)

(iv) The semi-amplitude of the second harmonic

The semi-amplitude of the second harmonic is shown in Fig. 4, the values ranging from about 0.8° to 1.3°F. The general distribution seems to be that the higher values are inland, or on coasts facing east, while the lower values are on coasts facing west or south. There are, however, several stations facing south where the parameter exceeds 1°F. and an area in the English Midlands where it is less than 1°F. In Fig. 5 the amplitude of the second harmonic is given as a percentage of that of the first. The values range mostly from 10 to 14 per cent, but the variations do not show any obvious regularity.

(v) The phase of the second harmonic

If the phase of the second harmonic is represented in the way used for the first, the resulting chart shows dates varying from 30th July to the 20th August but not falling into any pattern capable of ready description. However, the second harmonic is of much smaller amplitude than the first, so that its importance really lies in the way in which it modifies the first. Fig. 5a has been drawn to illustrate the ways in which it can do so. On comparing the three curves, it is obvious that the effect of a second harmonic with date of maximum agreeing with that of the first harmonic is to sharpen the summer peak and to flatten the winter trough. That is, the annual cycle has a long, rather equable winter, and a short summer with a well marked maximum. If the maximum of the second harmonic is displaced day by day to fall after that of the first, up to 45 days, the combined peak becomes progressively later, the winter becomes shorter and sharper, while the autumn decline of temperature becomes more rapid than the spring rise. As the shift is increased past 45 days the curve comes to resemble the second one, only inverted, with a short winter and a long equable summer. If the maximum of the second harmonic is shifted backwards relative to the first the result is like the third curve laterally reversed.

With this illustration in mind, the phase of the second harmonic is shown in Fig. 6 by the number of days by which the maximum of the second harmonic falls after that of the first. The distribution is a simple one, with maxima of about 20 days inland and low values on coasts, especially in the south-west. The effect of this displacement is twofold: (1) in inland districts of the British Isles the autumn decline of temperature is appreciably more rapid than the spring rise, an effect which is much less marked, or altogether absent on the coasts, and (2) the probable date of the hottest day (i.e., the maximum of the combination of the first and second harmonics) shows less variation than is shown in Fig. 3 for the date of maximum of the first harmonic alone. The actual distribution cannot be shown without extra calculation, but probably in all parts the date with the highest average temperature lies within a day or two of the end of July.

References

(1) Craddock, 1955. Meteorological Research Papers, Air Ministry, London, No.915.

(2) Craddock, 1955. Meteorological Research Papers, Air Ministry, London, No.917.

(3) M.O.571, 1953. Averages of temperature for Great Britain and Northern Ireland.

(4) M.O.488, 1952. Climatological Atlas of the British Isles.

Table 1. The stations used

Station	Lat. °N.	Long.	Alt. (m)	Period	
Aber	53°14'	4° 1'W	18.3	1925-50	*
Aberdeen	57°10'	2° 6'W	24.1	1921-47	*
Aberystwyth	52°25'	4° 4'W	137.2	1926-50	+
Achnashellac	57°29'	5°16'W	70.0	1923-50	*
Addington	51°22'	0° 4'W	143.3	1921-50	
Aldergrove	54°39'	6°13'W	67.1	1927-50	*
Ampleforth	54°12'	1° 5'W	94.5	1921-50	
Appleby	54°34'	2°30'W	134.1	1921-46	*
Arbroath	56°35'	2°35'W	28.3	1921-46	*
Ardtornish	56°34'	5°45'W	14.6	1921-45	*
Armagh	54°21'	6°39'W	62.0	1921-50	
Balmoral	57° 2'	3°12'W	283.5	1921-50	
Banff	57°40'	2°31'W	39.6	1926-50	*
Barnstaple	51° 5'	4° 3'W	7.6	1921-50	
Beachy Head	50°44'	0°15'E	152.4	1925-50	*
Bellingham	55°13'	2°18'W	259.0	1921-50	
Belper School	53° 1'	1°29'W	61.0	1921-50	
Berwick	55°46'	2° 0'W	23.2	1924-50	*
Birmingham (Sparkhill)	52°27'	1°51'W	131.0	1921-50	
Birr Castle	53° 5'	7°53'W	70.0	1921-50	
Blacksod Point	54° 4'	10° 4'W	5.0	1926-50	+
Bognor Regis	50°47'	0°41'W	7.3	1921-50	
Bolton	53°35'	2°27'W	103.6	1921-50	
Bradford	53°49'	1°46'W	134.1	1921-50	
Braemar	57° 0'	3°24'W	338.3	1921-50	
Bude	50°50'	4°33'W	15.2	1926-50	*
Bungay	52°25'	1°23'E	24.1	1921-48	*
Burnley	53°48'	2°15'W	140.2	1921-50	*
Buxton	53°16'	1°55'W	307.8	1926-50	*
Cambridge (Botanic Gdn.)	52°12'	0° 8'E	12.5	1921-50	
Camden Square	51°33'	0° 8'W	33.5	1921-50	
Canterbury	51°17'	1° 5'E	39.6	1921-44	*
Cardiff	51°28'	3°10'W	61.0	1921-50	
Cheltenham	51°54'	2° 3'W	64.0	1926-50	*
Chopwelwood	54°55'	1°47'W	137.2	1921-50	
Colmonell	55° 8'	4°57'W	51.8	1921-50	
Coventry	52°23'	1°29'W	73.1	1921-50	
Craibstone	57°11'	2°12'W	91.4	1925-50	*
Cranwell	53° 2'	0°30'W	61.0	1921-50	
Cromer	52°56'	1°17'E	54.9	1926-50	*
Croydon	51°21'	0° 7'W	67.1	1921-50	
Cullompton	50°51'	3°23'W	61.0	1921-50	
Cupar	56°19'	3° 1'W	64.0	1921-50	
Dalwhinnie	56°56'	4°14'W	359.7	1931-50	+
Darwen	53°41'	2°28'W	219.5	1921-50	
Donaghadee	54°38'	5°32'W	9.0	1921-42	+
Douglas	54°10'	4°28'W	85.3	1926-50	*
Dover	51° 7'	1°19'E	5.8	1926-50	*
Dublin (Phoenix Park)	53°22'	6°21'W	47.0	1921-50	
Dumfries	55° 3'	3°36'W	42.7	1921-50	
Dundee	56°28'	2°56'W	45.7	1921-50	
Dungavel	55°37'	4° 8'W	243.8	1921-48	*
Dungeness	50°55'	0°58'E	6.1	1921-50	
Durham	54°46'	1°35'W	103.6	1921-50	
East Ham	51°32'	0° 4'E	4.6	1921-50	
Edinburgh (Blackf'd Hill)	55°55'	3°11'W	134.1	1921-50	
Eskdalemuir	55°19'	3°12'W	240.8	1921-50	
Exmouth	50°36'	3°24'W	57.9	1921-50	

/Falmouth

Station	Lat. °N.	Long.	Alt. (m)	Period	
Falmouth	50° 9'	5° 5'W	51.8	1926-50	*
Felixstowe	51°57'	1°20'E	3.0	1921-50	
Fort Augustus	57° 8'	4°40'W	20.7	1921-47	*
Fortrose	57°35'	4° 8'W	21.0	1921-50	
Fort William	56°49'	5° 7'W	10.4	1932-50	+
Fowey	50°21'	4°38'W	15.2	1921-50	
Foynes	52°37'	9° 7'W	15.0	1921-44	+
Frampton Cotterell	51°32'	2°29'W	48.8	1921-50	
Garvagh	54°59'	6°36'W	36.6	1939-50	+
Glenbranter	56° 8'	5° 3'W	36.6	1926-50	*
Gordon Castle	57°37'	3° 5'W	30.5	1921-50	
Gorleston	52°35'	1°43'E	1.5	1921-50	
Greenock	55°56'	4°46'W	61.0	1921-50	
Greenwich	51°29'	0° 0'	45.7	1921-50	
Gulval	50° 8'	5°32'W	6.1	1925-50	*
Halstead	51°57'	0°38'E	42.7	1921-50	
Hampstead	51°34'	0°11'W	137.2	1921-50	
Haverfordwest	51°48'	4°58'W	39.6	1921-50	
Hawarden Bridge	53°12'	3° 1'W	5.2	1921-50	
Helensburgh	56° 1'	4°43'W	88.4	1921-50	
Hereford	52° 5'	2°45'W	88.4	1921-50	
Holyhead	53°19'	4°37'W	7.9	1921-50	
Hoylake	53°23'	3°12'W	7.0	1921-50	
Huddersfield (Ravensknowle)	53°38'	1°45'W	100.6	1921-50	
Hull	53°45'	0°16'W	2.4	1921-50	
Hunstanton	52°57'	0°29'E	30.5	1924-50	*
Hutton	53°44'	2°45'W	25.0	1921-50	
Ilfracombe	51°12'	4° 8'W	7.6	1926-50	*
Ilkley	53°55'	1°50'W	94.5	1923-50	*
Inverness	57°26'	4°13'W	73.1	1926-50	*
Kelso	55°36'	2°25'W	57.9	1921-50	
Kensington Palace	51°30'	0°10'W	24.4	1921-50	
Keswick	54°36'	3° 9'W	76.2	1921-50	
Kettins	56°32'	3°14'W	67.1	1921-50	
Kew	51°28'	0°19'W	5.5	1921-50	
Kilkenny	52°39'	7°14'W	55.0	1901-30	
Kilmarnock	55°37'	4°29'W	39.6	1921-50	
Kirkcaldy	56° 8'	3°10'W	42.7	1921-50	
Larkhill	51°11'	1°48'W	131.1	1921-50	
Lerwick	60° 8'	1°11'W	82.3	1921-50	
Leuchars	56°23'	2°53'W	10.1	1921-50	
Liverpool	53°24'	3° 4'W	61.0	1921-50	
Long Ashton	51°26'	2°40'W	48.8	1921-50	
Luton	51°54'	0°25'W	115.8	1921-50	
Lympne	51° 5'	1° 1'E	103.6	1921-50	
Macclesfield	53°16'	2° 8'W	152.4	1921-50	
Malin Head	55°22'	7°20'W	26.0	1921-50	
Malvern	52° 8'	2°18'W	115.8	1926-50	*
Manchester	53°28'	2°14'W	39.6	1921-50	
Marchmont	55°44'	2°25'W	152.4	1921-50	
Markree Castle	54°11'	8°27'W	37.0	1921-50	
Marlborough	51°25'	1°44'W	128.0	1921-50	
Morecambe	54° 4'	2°52'W	7.0	1926-50	*
Morpeth (Cockle Park)	55°13'	1°41'W	100.6	1921-50	
Newport (Mon.)	51°35'	3° 0'W	82.3	1921-50	
Newquay	50°25'	5° 4'W	54.9	1926-50	*
Newton Rigg	54°40'	2°47'W	170.7	1921-47	*
North Berwick	56° 3'	2°43'W	36.6	1923-50	*
Norwich	52°37'	1°17'E	33.5	1921-47	*
Nottingham Castle	52°57'	1° 9'W	57.9	1921-50	

Station	Lat. °N.	Long.	Alt. (m)	Period
Oxford	51°46'	1°16'W	64.0	1921-50
Paisley	55°51'	4°26'W	33.5	1921-50
Perth	56°24'	3°27'W	23.5	1921-50
Plymouth (Mount Batten)	50°21'	4° 7'W	26.5	1921-50
Portland Bill	50°32'	2°27'W	9.7	1921-50
Porton	51° 7'	1°42'W	109.7	1921-50
Reading (Shinfield)	51°25'	0°57'W	61.0	1921-50
Reading University	51°27'	0°58'W	45.7	1921-50
Renfrew	55°52'	4°26'W	8.8	1921-50
Rhayader	52°18'	3°31'W	231.7	(1921-34 * (1936-50
Rhyl	53°19'	3°29'W	9.4	1926-50
Roches Point	51°48'	8°15'W	10.0	1921-50
Ross-on-Wye	51°55'	2°35'W	67.1	1921-50
Rothamsted	51°48'	0°22'W	128.0	1921-50
Rothesay	55°50'	5° 2'W	61.0	1921-50
Rothwell	55° 0'	3°26'W	20.4	1921-50
Ryde	50°44'	1°10'W	4.0	1921-50
St. Anne's Head	51°41'	5°10'W	42.7	1921-50
Sandown	50°39'	1° 9'W	4.0	1921-50
Scarborough	54°17'	0°24'W	36.6	1926-50 *
Scilly	49°56'	6°18'W	48.8	1921-50
Seskin (Carrick on Suir)	52°21'	7°24'W	165.0	1921-50
Shaftesbury	51° 1'	2°12'W	207.3	1921-50
Sheffield	53°23'	1°29'W	131.1	1921-50
Shoeburyness	51°32'	0°49'E	3.4	1921-50
Shrewsbury	52°43'	2°43'W	54.9	1931-50 +
Sidmouth	50°41'	3°14'W	7.6	1921-50
Skegness	53° 9'	0°21'E	4.6	1926-50 *
South Farnborough	51°17'	0°45'W	70.1	1921-50
Southampton	50°55'	1°24'W	19.8	1921-50
Southport	53°37'	3° 0'W	10.7	1921-50
Spurn Head	53°35'	0° 7'E	8.8	1921-50
Stirling	56° 7'	3°56'W	45.7	1921-50
Stonyhurst	53°51'	2°28'W	115.8	1921-50
Stornoway	58°13'	6°20'W	3.4	1921-50
Swansea	51°37'	3°55'W	9.8	1926-50 *
Tavistock	50°33'	4°10'W	140.2	1921-50
Tiree	56°30'	6°53'W	8.8	1927-50 +
Tunbridge Wells	51° 8'	0°16'E	106.7	1926-50 *
Turnberry	55°19'	4°50'W	19.2	1921-50
Tynemouth	55° 1'	1°25'W	33.5	1921-50
Ushaw	54°47'	1°39'W	179.8	1921-50
Valentia	51°56'	10°15'W	13.7	1921-50
Ventnor Hospital	50°36'	1°13'W	18.3	1921-50
Wakefield	53°40'	1°30'W	33.5	1921-50
Welshpool	52°39'	3° 8'W	76.2	1921-50
West Linton	55°45'	3°21'W	249.9	1921-50
Westminster	51°30'	0° 8'W	8.2	1921-50
Wick	58°27'	3° 5'W	36.6	1921-50
Wisley	51°17'	0°26'W	45.7	1921-50
Woburn	52° 1'	0°35'W	88.4	1921-50
Wolfelee	55°23'	2°39'W	164.6	1921-50
York	53°57'	1° 5'W	17.4	1921-50

* Less than 30 years data for means, but missing years are estimated by comparison with nearest complete station.

\+ Less than 30 years data, with missing years not estimated. (See p.1 of M.O.571.)

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Table 2

Harmonic parameters for stations in the British Isles

Station	a_0	a_1	b_1	a_2	b_2	A_1	ϕ_1	A_2	ϕ_2
Aber	50.55	- 8.09	-4.38	+0.40	+1.01	9.19	30/7	1.09	5/8
Aberdeen	47.00	- 8.44	-4.16	+0.62	+1.28	9.41	28/7	1.42	2/8
Aberystwyth	50.43	- 8.83	-4.69	+0.04	+0.82	10.00	30/7	0.82	16/8
Achnashellac	46.56	- 8.96	-3.52	+0.44	+0.97	9.63	23/7	1.06	4/8
Addington	49.45	-11.26	-4.62	+0.13	+1.17	12.17	24/7	1.18	13/8
Aldergrove	48.17	- 8.82	-3.80	+0.40	+1.08	9.60	25/7	1.15	6/8
Ampleforth	47.85	-10.50	-4.42	+0.24	+1.11	11.39	25/7	1.13	10/8
Appleby	46.74	-10.44	-3.80	+0.29	+0.97	11.11	22/7	1.01	8/8
Arbroath	47.04	- 9.00	-4.04	+0.19	+1.30	9.86	26/7	1.32	12/8
Ardtornish	47.60	- 8.75	-3.52	+0.50	+0.90	9.43	24/7	1.03	1/8
Armagh	48.79	- 9.07	-3.62	+0.51	+1.12	9.76	24/7	1.23	4/8
Balmoral	43.76	- 9.98	-4.04	+0.63	+1.18	10.76	24/7	1.34	1/8
Banff	47.24	- 8.97	-4.06	+0.25	+1.01	9.85	26/7	1.04	9/8
Barnstaple	51.07	- 8.52	-4.11	+0.34	+1.00	9.46	28/7	1.06	7/8
Beachy Head	49.24	- 9.39	-5.46	-0.11	+0.96	10.86	1/8	0.96	20/8
Bellingham	45.21	-10.30	-4.05	+0.38	+0.96	11.07	23/7	1.04	5/8
Belper School	48.73	-10.98	-4.23	+0.40	+1.10	11.76	23/7	1.17	6/8
Berwick	47.33	- 8.50	-4.30	+0.37	+1.27	9.53	29/7	1.32	8/8
Birmingham (Sparkhill)	49.33	-11.24	-4.32	+0.34	+1.15	12.04	23/7	1.20	8/8
Birr Castle	49.30	- 8.81	-3.54	+0.38	+1.26	9.49	24/7	1.32	7/8
Blacksod Point	50.38	- 6.78	-3.74	+0.06	+0.80	7.74	31/7	0.80	13/8
Bognor Regis	50.74	- 9.99	-5.09	+0.13	+1.03	11.21	29/7	1.04	13/8
Bolton	48.58	-10.44	-4.24	+0.30	+0.96	11.27	24/7	1.01	7/8
Bradford	47.95	-10.36	-4.49	+0.43	+1.06	11.29	25/7	1.15	5/8
Braemar	43.57	-10.05	-4.00	+0.72	+1.08	10.81	24/7	1.30	29/8
Bude	50.99	- 8.10	-4.47	+0.27	+0.93	9.25	31/7	0.97	8/8
Bungay	49.56	-11.65	-4.81	+0.01	+1.29	12.60	24/7	1.29	16/8
Burnley	47.53	-10.23	-4.36	+0.42	+1.05	11.12	25/7	1.13	5/8
Buxton	45.92	-10.17	-4.43	+0.46	+0.94	11.10	25/7	1.05	3/8
Cambridge (Botanic Gdn.)	49.73	-11.40	-4.41	+0.22	+1.29	12.22	23/7	1.31	11/8
Camden Square	51.72	-12.11	-4.48	+0.23	+1.11	12.91	22/7	1.13	10/8
Canterbury	50.60	-11.27	-4.67	+0.04	+1.24	12.19	24/7	1.24	15/8
Cardiff	50.25	-10.03	-4.32	+0.26	+0.97	10.92	25/7	1.01	8/8
Cheltenham	50.12	-11.13	-4.25	+0.40	+1.25	11.91	25/7	1.32	7/8
Chopwelwood	47.09	-10.01	-4.26	+0.36	+1.14	10.88	25/7	1.20	7/8
Colmonell	48.08	- 8.63	-3.95	+0.31	+0.88	9.49	26/7	0.93	6/8
Coventry	49.22	-11.31	-4.29	+0.31	+1.20	12.10	25/7	1.24	9/8
Craibstone	46.04	- 8.75	-4.29	+0.35	+1.05	9.74	28/7	1.11	7/8
Cranwell	48.79	-11.01	-4.55	+0.16	+1.31	11.92	24/7	1.32	12/8
Cromer	49.85	-10.49	-5.19	+0.06	+1.33	11.71	28/7	1.33	18/8
Croydon	50.61	-11.08	-4.56	+0.19	+1.22	11.98	24/7	1.24	12/8
Cullompton	50.61	-10.44	-3.97	+0.38	+1.09	11.17	23/7	1.15	6/8
Cupar	47.11	- 9.95	-3.92	+0.37	+1.38	10.70	23/7	1.43	9/8
Dalwhinnie	43.23	- 9.76	-4.25	+0.41	+1.08	10.65	25/7	1.15	6/8
Darwen	47.43	-10.48	-4.32	+0.53	+0.98	11.34	24/7	1.12	2/8
Donaghadee	48.90	- 7.29	-4.12	+0.37	+1.05	8.37	31/7	1.11	6/8
Douglas	48.81	- 7.82	-4.42	+0.49	+0.75	8.98	1/8	0.90	30/7
Dover	50.83	-10.16	-5.32	-0.10	+0.98	11.47	30/7	0.98	19/8
Dublin (Phoenix Park)	48.96	- 8.71	-3.92	+0.55	+1.31	9.55	26/7	1.42	4/8
Dumfries	47.69	- 9.77	-3.91	+0.45	+1.07	10.52	24/7	1.16	5/8
Dundee	47.23	- 9.89	-4.08	+0.46	+1.29	10.69	24/7	1.37	6/8
Dungavel	44.85	- 9.33	-3.90	+0.55	+0.95	10.12	25/7	1.10	1/8
Dungeness	50.33	- 9.84	-5.64	-0.11	+1.09	11.34	1/8	1.09	19/8
Durham	47.56	-10.01	-4.40	+0.39	+1.21	10.94	26/7	1.27	7/8
East Ham	51.16	-11.55	-4.68	+0.26	+1.25	12.47	24/7	1.27	10/8
Edinburgh (Blackf'd Hill)	47.44	- 9.09	-4.30	+0.61	+1.16	10.06	27/7	1.31	2/8
Eskdalemuir	44.65	- 9.59	-4.00	+0.63	+0.98	10.40	24/7	1.16	31/7
Exmouth	50.61	- 9.03	-4.56	+0.36	+1.09	10.11	29/7	1.15	7/8

/Falmouth

Station	a_0	a_1	b_1	a_2	b_2	A_1	ϕ_1	A_2	ϕ_2
Falmouth	52.14	- 8.10	-4.41	+0.26	+1.06	9.22	31/7	1.09	9/8
Felixstowe	50.38	-10.96	-5.66	+0.05	+1.26	12.33	29/7	1.26	15/8
Fort Augustus	46.76	- 9.25	-3.73	+0.44	+1.29	9.98	25/7	1.36	7/8
Fortrose	47.94	- 9.01	-3.72	+0.15	+0.86	9.74	24/7	0.87	11/8
Fort William	47.52	- 9.17	-3.76	+0.38	+1.17	9.91	24/7	1.23	7/8
Fowey	52.00	- 8.22	-4.34	+0.19	+1.00	9.30	30/7	1.02	11/8
Foynes	50.34	- 8.64	-3.53	+0.72	+1.15	9.33	24/7	1.36	31/7
Frampton Cotterell	49.92	-10.96	-4.05	+0.30	+1.12	11.69	25/7	1.16	8/8
Garvagh	48.05	- 9.30	-3.63	-0.17	+0.67	9.98	23/7	0.69	13/8
Glenbranter	47.03	- 9.26	-3.57	+0.43	+1.01	9.92	23/7	1.10	4/8
Gordon Castle	47.32	- 9.34	-3.85	+0.46	+1.26	10.10	24/7	1.34	6/8
Gorleston	49.86	-10.06	-5.56	-0.01	+1.31	11.49	31/7	1.31	16/8
Greenock	48.39	- 9.16	-3.98	+0.61	+0.88	9.99	25/7	1.07	30/7
Greenwich	50.63	-11.51	-4.54	+0.33	+1.38	12.37	23/7	1.42	9/8
Gulval	52.04	- 7.63	-4.28	+0.33	+0.96	8.75	31/7	1.01	6/8
Halstead	49.95	-11.76	-4.45	+0.04	+1.29	12.57	23/7	1.29	15/8
Hampstead	49.26	-11.55	-4.55	+0.13	+1.19	12.41	23/7	1.20	13/8
Haverfordwest	49.77	- 8.30	-4.29	+0.45	+0.97	9.34	29/7	1.07	3/8
Hawarden Bridge	50.05	-10.01	-4.18	+0.31	+1.12	10.85	24/7	1.16	8/8
Helensburgh	47.49	- 9.51	-3.96	+0.52	+0.92	10.30	24/7	1.06	1/8
Hereford	49.14	-10.65	-4.01	+0.43	+1.12	11.38	22/7	1.20	5/8
Holyhead	50.41	- 7.38	-4.70	+0.21	+0.84	8.78	1/8	0.87	9/8
Hoylake	49.90	- 9.79	-4.41	+0.36	+1.09	10.74	26/7	1.15	7/8
Huddersfield (Ravensknowle)	48.39	-10.64	-4.40	+0.57	+1.19	11.51	24/7	1.32	3/8
Hull	49.76	-10.70	-4.65	+0.25	+1.40	11.66	25/7	1.42	11/8
Hunstanton	49.84	-10.96	-4.91	-0.03	+1.26	12.01	26/7	1.26	20/8
Hutton	48.75	-10.09	-4.23	+0.20	+1.09	10.94	25/7	1.11	11/8
Ilfracombe	51.89	- 8.05	-4.82	+0.20	+0.95	9.38	2/8	0.98	10/8
Ilkley	47.94	-10.69	-4.33	+0.42	+1.11	11.53	24/7	1.18	6/8
Inverness	46.76	- 8.89	-3.86	+0.52	+1.23	9.70	25/7	1.33	5/8
Kelso	46.94	-10.17	-3.83	+0.37	+1.11	10.87	22/7	1.17	7/8
Kensington Palace	51.64	-11.56	-4.47	+0.20	+1.20	12.40	23/7	1.21	11/8
Keswick	48.49	- 9.41	-4.08	+0.57	+0.97	10.26	25/7	1.12	1/8
Kettins	46.38	-10.30	-3.77	+0.34	+1.27	10.97	22/7	1.31	8/8
Kew	50.76	-11.44	-4.36	+0.50	+1.21	12.24	23/7	1.31	6/8
Kilkenny	48.96	- 9.20	-3.51	+0.69	+1.23	9.85	23/7	1.41	1/8
Kilmarnock	48.13	- 9.82	-3.77	+0.36	+1.17	10.52	23/7	1.23	8/8
Kirkcaldy	47.69	- 9.75	-4.04	+0.39	+1.26	10.56	24/7	1.32	7/8
Larkhill	48.92	-10.68	-4.40	+0.17	+1.18	11.55	24/7	1.19	12/8
Lerwick	44.78	- 6.75	-4.19	+0.63	+1.03	7.94	4/8	1.21	31/7
Leuchars	47.36	- 9.33	-4.05	+0.29	+1.31	10.17	25/7	1.34	10/8
Liverpool	49.35	- 9.73	-4.31	+0.37	+0.91	10.64	26/7	0.98	5/8
Long Ashton	50.17	-10.25	-4.22	+0.31	+1.09	11.08	24/7	1.13	8/8
Luton	48.96	-11.17	-4.56	+0.24	+1.30	12.06	24/7	1.32	11/8
Lympne	49.37	-10.56	-5.06	-0.12	+1.19	11.71	27/7	1.19	19/8
Macclesfield	48.10	-10.88	-4.22	+0.34	+1.12	11.67	23/7	1.17	8/8
Malin Head	48.82	- 6.79	-4.03	+0.16	+1.00	7.90	2/8	1.01	11/8
Malvern	49.97	-11.04	-4.25	+0.26	+1.15	11.83	23/7	1.18	10/8
Manchester	49.81	-10.45	-4.09	+0.37	+1.08	11.22	23/7	1.14	7/8
Marchmont	46.42	- 9.86	-4.08	+0.45	+1.18	10.67	24/7	1.26	5/8
Markree Castle	48.69	- 8.39	-3.42	+0.27	+1.13	9.06	24/7	1.16	9/8
Marlborough	48.42	-10.59	-4.09	+0.35	+1.17	11.35	23/7	1.23	8/8
Morecambe	49.27	-10.27	-4.48	+0.34	+0.92	11.20	25/7	0.98	6/8
Morpeth (Cockle Park)	46.79	- 9.42	-4.34	+0.43	+1.23	10.37	27/7	1.30	6/8
Newport (Mon.)	50.37	-10.63	-4.14	+0.33	+0.98	11.41	24/7	1.04	7/8
Newquay	51.31	- 7.82	-4.46	+0.25	+1.03	9.00	1/8	1.06	9/8
Newton Rigg	46.88	-10.14	-3.91	+0.49	+0.99	10.87	23/7	1.10	3/8
North Berwick	47.70	- 9.21	-4.19	+0.28	+1.16	10.12	26/7	1.20	9/8
Norwich	49.79	-11.54	-4.69	+0.04	+1.29	12.46	24/7	1.29	15/8
Nottingham Castle	49.58	-11.00	-4.37	+0.31	+1.20	11.84	23/7	1.24	9/8

/Oxford

Station	a_0	a_1	b_1	a_2	b_2	A_1	ϕ_1	A_2	ϕ_2
Oxford	50.20	-11.18	-4.32	+0.22	+1.26	11.99	23/7	1.28	11/8
Paisley	48.68	- 9.87	-3.74	+0.55	+1.02	10.56	23/7	1.16	2/8
Perth	47.47	-10.55	-3.75	+0.40	+1.16	11.20	21/7	1.23	6/8
Plymouth (Mount Batten)	51.51	- 8.07	-4.51	+0.32	+0.90	9.24	31/7	0.95	6/8
Portland Bill	51.46	- 7.58	-5.63	+0.11	+0.83	9.44	8/8	0.84	12/8
Porton	48.81	-10.75	-4.35	+0.16	+1.19	11.59	24/7	1.20	12/8
Reading (Shinfield)	49.83	-11.28	-4.37	+0.25	+1.20	12.09	23/7	1.23	10/8
Reading University	50.63	-11.37	-4.24	+0.20	+1.16	12.14	22/7	1.18	11/8
Renfrew	47.69	- 9.63	-3.75	+0.42	+1.17	10.33	23/7	1.24	6/8
Rhyader	47.16	- 9.56	-4.20	+0.46	+1.03	10.44	26/7	1.13	4/8
Rhyl	50.13	- 8.98	-4.41	+0.33	+1.10	10.01	28/7	1.14	8/8
Roches Point	51.22	- 7.05	-3.98	+0.44	+1.07	8.09	31/7	1.16	5/8
Ross-on-Wye	50.00	-10.28	-4.11	+0.40	+1.12	11.07	24/7	1.19	6/8
Rothamsted	48.57	-11.21	-4.53	+0.14	+1.25	12.09	24/7	1.26	13/8
Rothesay	47.82	- 8.28	-3.88	+0.51	+0.81	9.14	27/7	0.96	31/7
Rothwell	47.60	-10.28	-3.92	+0.31	+1.06	11.00	23/7	1.10	8/8
Ryde	51.63	-10.24	-4.92	+0.26	+0.99	11.36	28/7	1.02	9/8
St. Anne's Head	50.68	- 7.01	-4.84	+0.35	+0.74	8.52	6/8	0.82	3/8
Sandown	51.55	- 9.80	-5.09	+0.22	+0.96	11.05	29/7	0.98	10/8
Scarborough	49.62	- 9.56	-4.72	+0.05	+1.37	10.66	28/7	1.37	15/8
Scilly	52.58	- 6.48	-4.45	+0.29	+1.10	7.86	5/8	1.14	9/8
Seskin (Carrick on Suir)	48.96	- 9.06	-3.68	+0.52	+1.17	9.78	24/7	1.28	3/8
Shaftesbury	48.81	-10.30	-4.48	+0.13	+1.07	11.23	25/7	1.08	13/8
Sheffield	49.22	-10.49	-4.51	+0.46	+1.10	11.42	25/7	1.19	5/8
Shoeburyness	50.47	-11.11	-5.22	+0.12	+1.42	12.28	27/7	1.43	14/8
Shrewsbury	49.46	-10.86	-4.24	+0.25	+1.01	11.66	23/7	1.04	9/8
Sidmouth	50.90	- 8.87	-4.65	+0.26	+1.07	10.02	30/7	1.10	7/8
Skegness	48.95	-10.37	-5.06	-0.01	+1.33	11.54	28/7	1.33	16/8
South Farnborough	50.01	-11.08	-4.34	+0.31	+1.24	11.90	23/7	1.28	9/8
Southampton	51.06	-10.76	-4.44	+0.18	+1.07	11.64	24/7	1.08	11/8
Southport	49.30	- 9.95	-4.35	+0.25	+1.05	10.86	26/7	1.08	9/8
Spurn Head	49.43	- 9.86	-5.43	+0.02	+1.24	11.25	31/7	1.24	16/8
Stirling	47.99	-10.09	-3.74	+0.46	+1.16	10.76	22/7	1.25	5/8
Stonyhurst	48.03	-10.20	-4.26	+0.43	+0.90	11.05	25/7	1.00	3/8
Stornoway	47.14	- 6.90	-3.74	+0.54	+1.07	7.85	30/7	1.20	3/8
Swansea	51.55	- 9.59	-4.54	+0.26	+0.87	10.61	27/7	0.91	8/8
Tavistock	50.12	- 9.00	-4.14	+0.26	+0.94	9.91	27/7	0.98	8/8
Tiree	48.62	- 6.82	-4.04	+0.18	+0.68	7.92	3/8	0.71	9/8
Tunbridge Wells	49.38	-11.44	-4.56	+0.09	+1.21	12.31	24/7	1.21	14/8
Turnberry	48.72	- 8.36	-4.07	+0.24	+0.82	9.29	28/7	0.85	8/8
Tynemouth	48.55	- 8.55	-4.72	+0.23	+1.30	9.77	31/7	1.32	11/8
Ushaw	47.22	-10.17	-4.37	+0.30	+1.21	11.07	25/7	1.25	7/8
Valentia	51.34	- 6.77	-3.57	+0.44	+1.00	7.65	30/7	1.09	4/8
Ventnor Hospital	51.98	- 9.43	-5.17	-0.04	+0.89	10.76	30/7	0.89	17/8
Wakefield	49.26	-10.94	-4.35	+0.28	+1.20	11.77	23/7	1.24	9/8
Welshpool	48.80	-10.20	-4.02	+0.45	+1.07	10.96	23/7	1.16	10/8
West Linton	44.79	- 9.71	-3.92	+0.57	+1.10	10.48	24/7	1.24	2/8
Westminster	51.98	-11.47	-4.51	+0.17	+1.16	12.32	23/7	1.18	12/8
Wick	46.01	- 6.94	-4.17	+0.31	+1.04	8.10	1/8	1.09	8/8
Wisley	50.26	-11.30	-4.30	+0.22	+1.26	12.09	23/7	1.28	11/8
Woburn	48.80	-11.08	-4.47	+0.25	+1.29	11.95	24/7	1.32	11/8
Wolfelee	45.49	- 9.99	-3.72	+0.52	+1.02	10.66	22/7	1.15	2/8
York	49.34	-10.85	-4.29	+0.34	+1.24	11.67	23/7	1.28	8/8

FIG1 ANNUAL MEAN TEMPERATURE 1921-1950
IN DEGREES FAHRENHEIT.

M.R.P. 970

TEMPERATURES
CORRECTED TO
MEAN SEA LEVEL

FIG 2. SEMI-AMPLITUDE OF FIRST HARMONIC IN DEGREES FAHRENHEIT.

M.R.P. 970

ALTITUDES GIVEN IN METRES.

FIG 3. PHASE OF FIRST HARMONIC
DATE OF MAXIMUM. M.R.P. 970

FIG 4. SEMI-AMPLITUDE OF SECOND HARMONIC IN DEGREES FAHRENHEIT.

M.R.P. 970

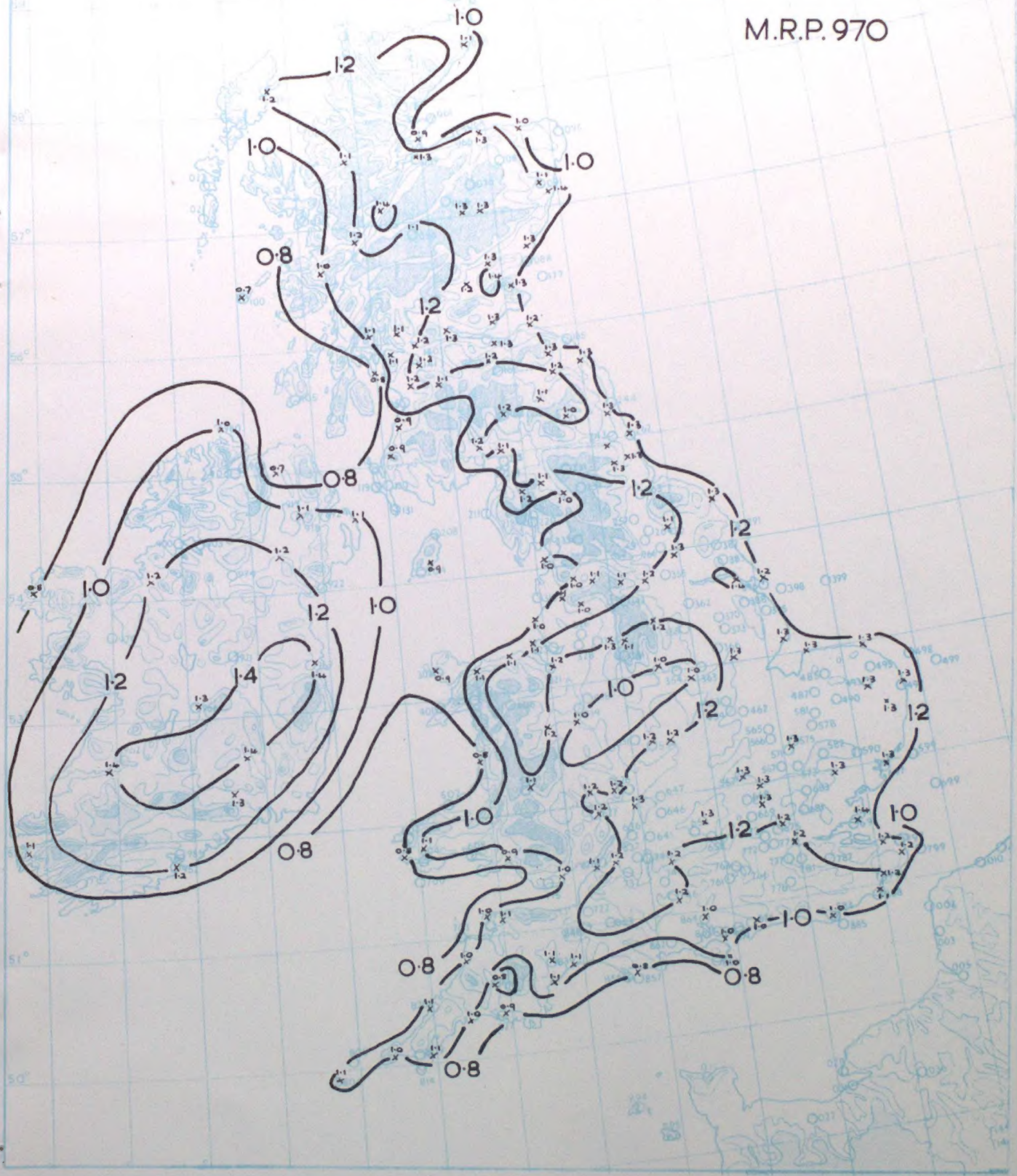

FIG 5. RATIO OF AMPLITUDES OF THE FIRST AND SECOND HARMONICS ($A_2/A_1 \times 100$)

M.R.P. 970

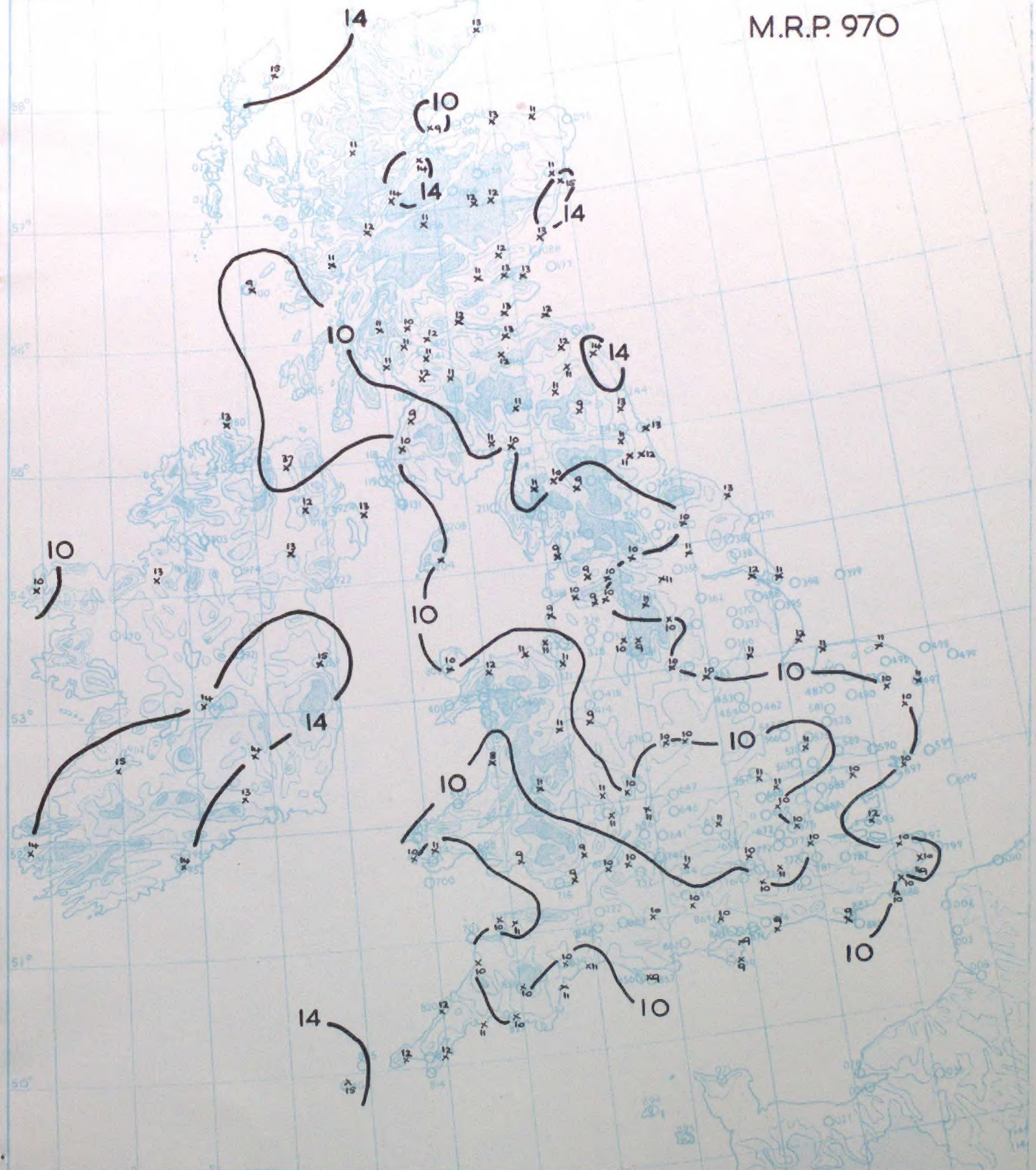

FIG 5A EXAMPLES ILLUSTRATING THE MODIFICATION OF A FIRST HARMONIC WITH BASIC PERIOD ONE YEAR BY A SECOND HARMONIC HAVING ONE FIFTH THE AMPLITUDE OF THE FIRST.

M.R.P. 970

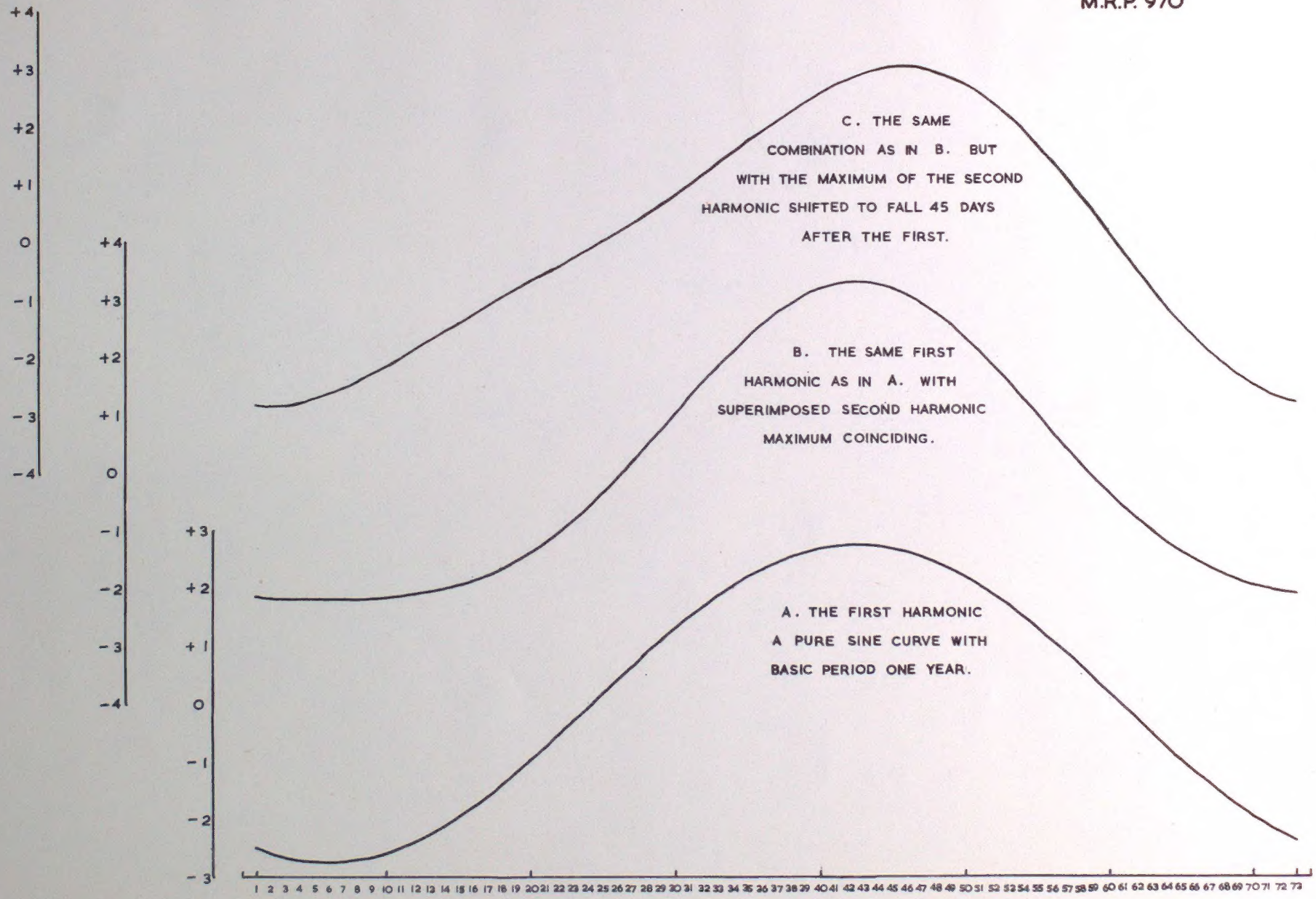

FIG 6. NUMBER OF DAYS BETWEEN DATES OF MAXIMUM OF FIRST AND SECOND HARMONICS.

M.R.P. 970